



Self-Raman Nd:YVO₄ laser and electro-optic technology for space-based sodium lidar instrument

SPIE Solid State Lasers XXIII: Technology and Devices
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Sodium lidar instrument

AGENDA



- Heliophysics in the Earth mesosphere with spectroscopy of sodium
- Key candidate technology for space-based sodium lidar:
 - Laser transmitter: Self-Raman Nd:YVO₄
 - Laser spectroscopic technique: leverage from ASCENDS
 - Laser receiver: filter
 - Laser receiver: single photon detectors



Heliophysics with sodium lidar



- **Ablation from meteors** is believed to be the chief source of **metals** such as Na, Mg, K, Fe, and Ca in the **middle atmosphere**.
- Metal (e.g. sodium) fluorescence lidar can provide temperature measurements in the Earth's atmosphere mesopause region (75 - 115 km).
- This will enable scientists to delineate and understand the middle and upper atmosphere chemistry, structure and dynamics, especially the impact of gravity waves – the parameterization of which is a fundamental issue in current atmospheric modeling for climate and meteorology.
- **In summary, this helps to delineate and separate solar vs. Earth induced heat causing change in the Earth atmospheric temperature.**

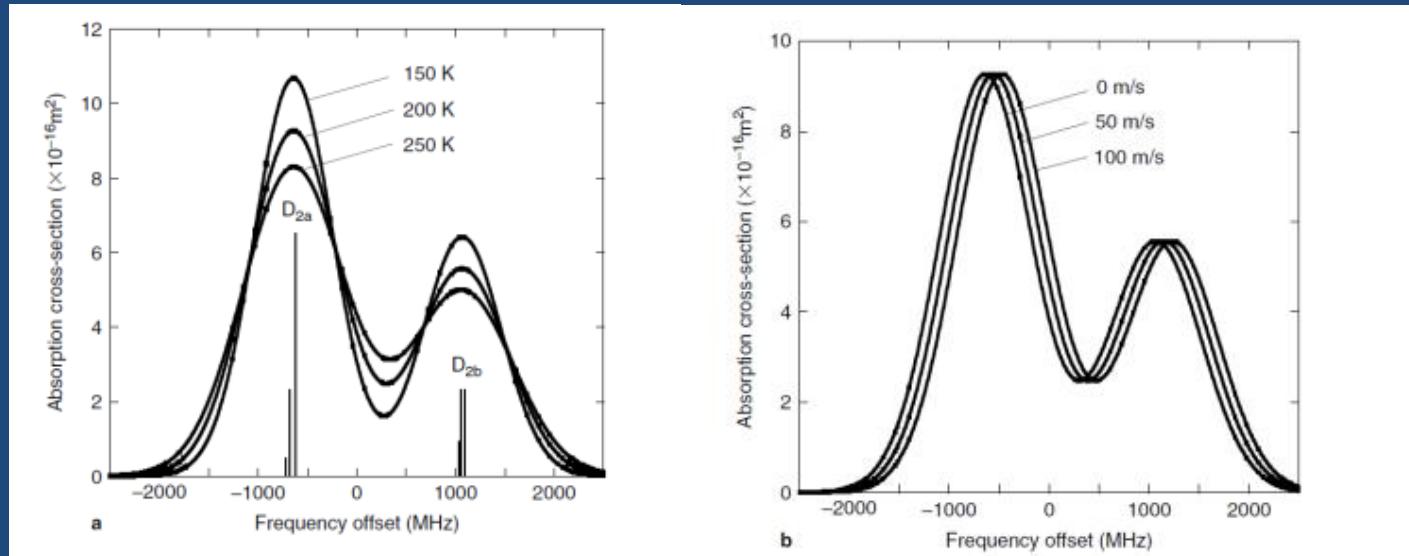


Atmospheric Sodium spectra

Temperature and wind effects



- The D2 resonance line of atomic sodium is **589.159 nm**
- The D2 resonance line of Na is a Doppler broadened doublet composed of six hyperfine lines as shown below.



- The Doppler broadening of the lines is a **function of temperature** and the ratio of the D2a peak to the value at the minimum between the peaks is a very sensitive function of temperature.
- The **wind speed** may be inferred from the **Doppler shift** induced to the structure of the line as shown above.



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Sodium space-based lidar - leverage

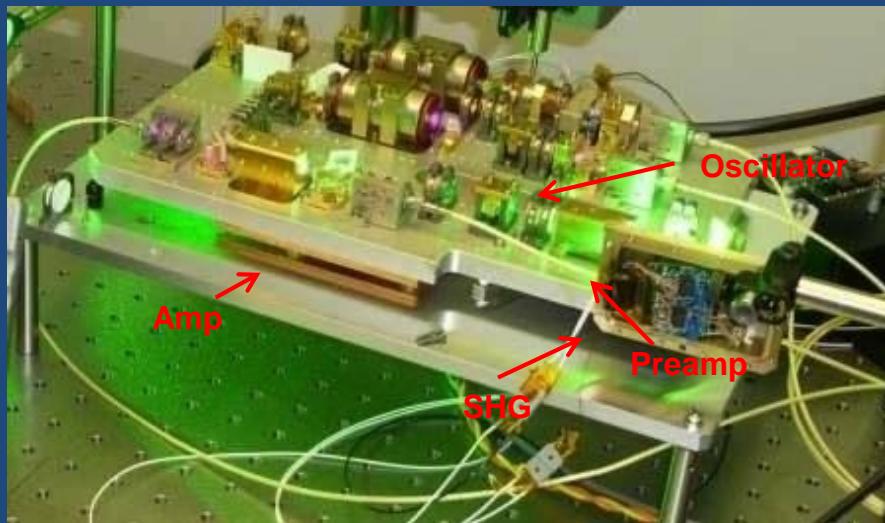
ICESat2/ATLAS laser

ICESat = Ice Cloud & land Elevation Satellite

ATLAS = Advanced Topographic Laser
Altimeter System

2017 launch

9W @ 532 nm Nd:YVO₄ laser
built by Fibertek Inc.



REFERENCE:

"High efficiency laser designs for airborne and space-based lidar remote sensing systems"

F. Hovis, R. Burnham, M. Storm, R. Edwards, P. Burns, E. Sullivan, J. Edelman, K. Andes, B. Walters, K. Le, C. Culpepper, J. Rudd, T. Chuang, X. Dang, J. Hwang, and T. Wysocki

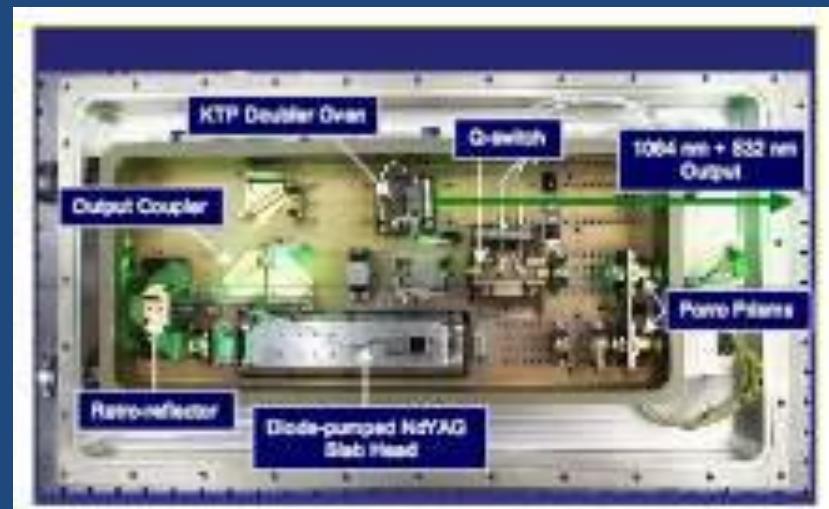
CALIPSO/CALIOP laser

CALIPSO = Cloud Aerosol Lidar and Infrared
Pathfinder Satellite Observations

CALIOP = Cloud-Aerosol LiDAR with Orthogonal
Polarization

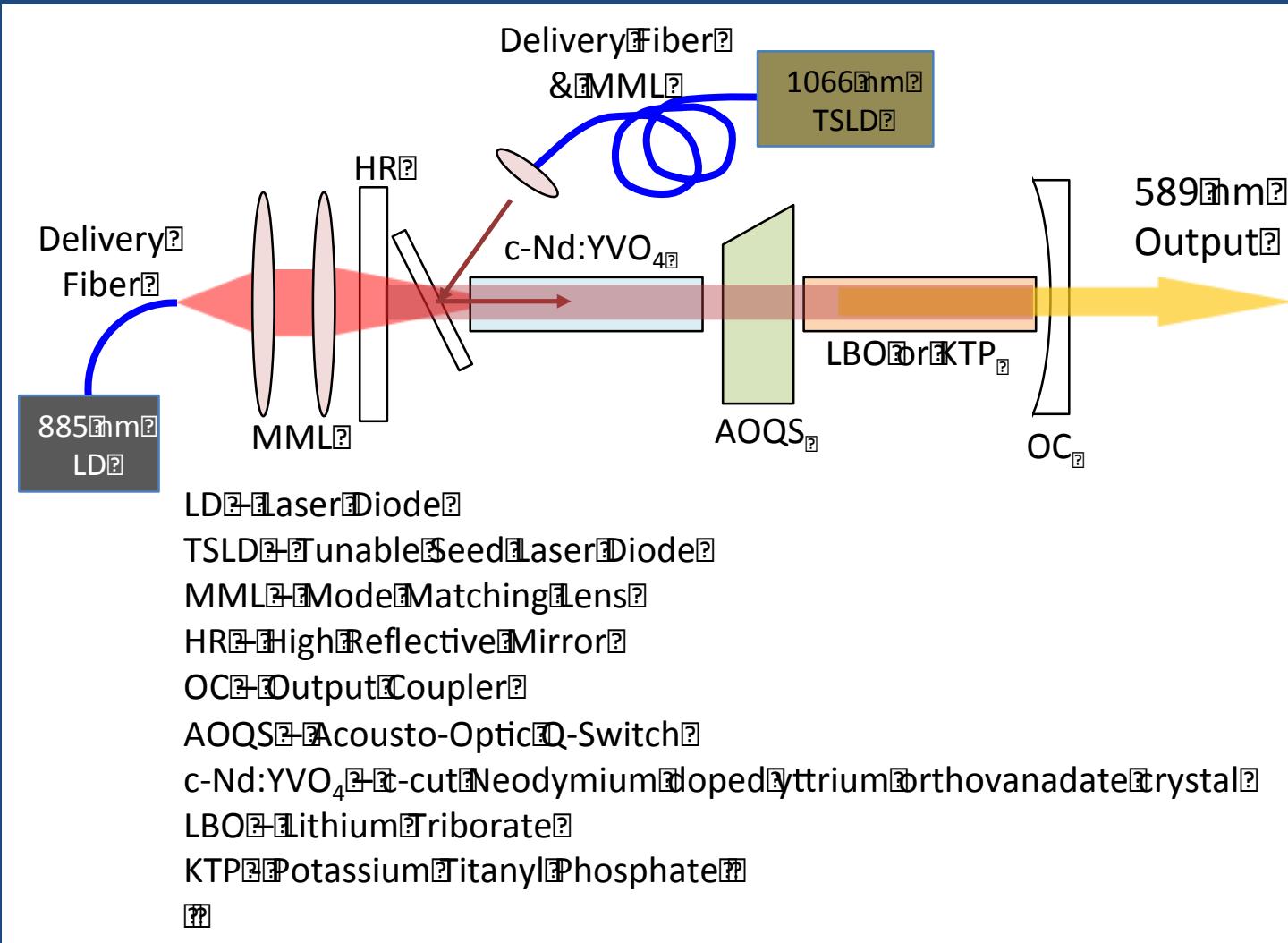
2006 launch

2.2 W @ 532 nm, 2.2W @1064 nm
Nd:YAG laser built by Fibertek Inc





Self-Raman Nd:YVO₄ Laser for Sodium Spectroscopy

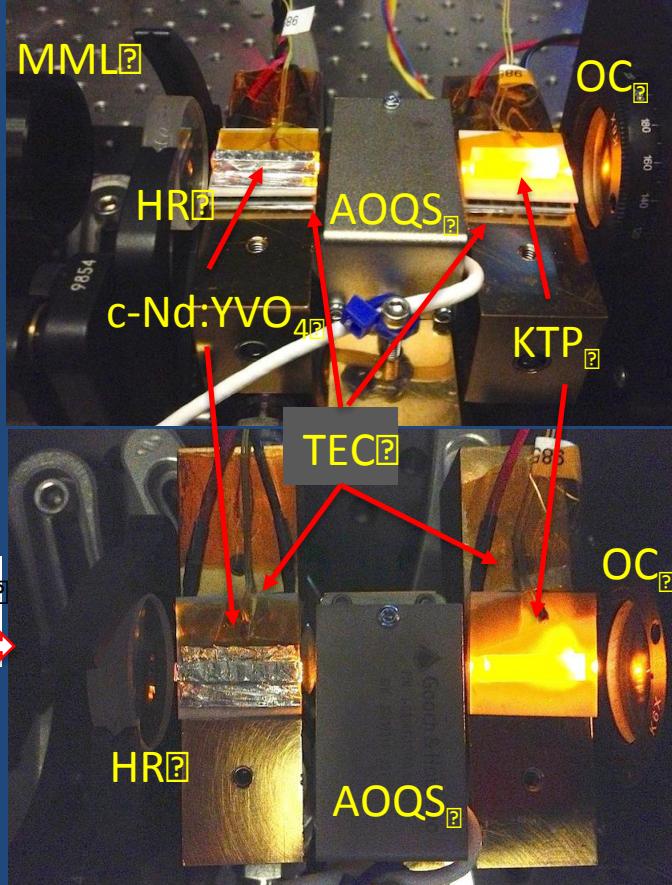




Nd:YVO₄ Self-Raman laser NASA-GSFC breadboard



LD = Laser Diode
MML = Mode Matching Lens
HR = High Reflective Mirror
OC = Output Coupler
AOQS = Acousto-Optic Q-Switch
c-Nd:YVO₄ = c-cut Neodymium Doped yttrium Orthovanadate Crystal
KTP = Potassium Titanyl Phosphate
TEC = Thermoelectric Cooler





Laser for Sodium Spectroscopy

Tuning vanadate

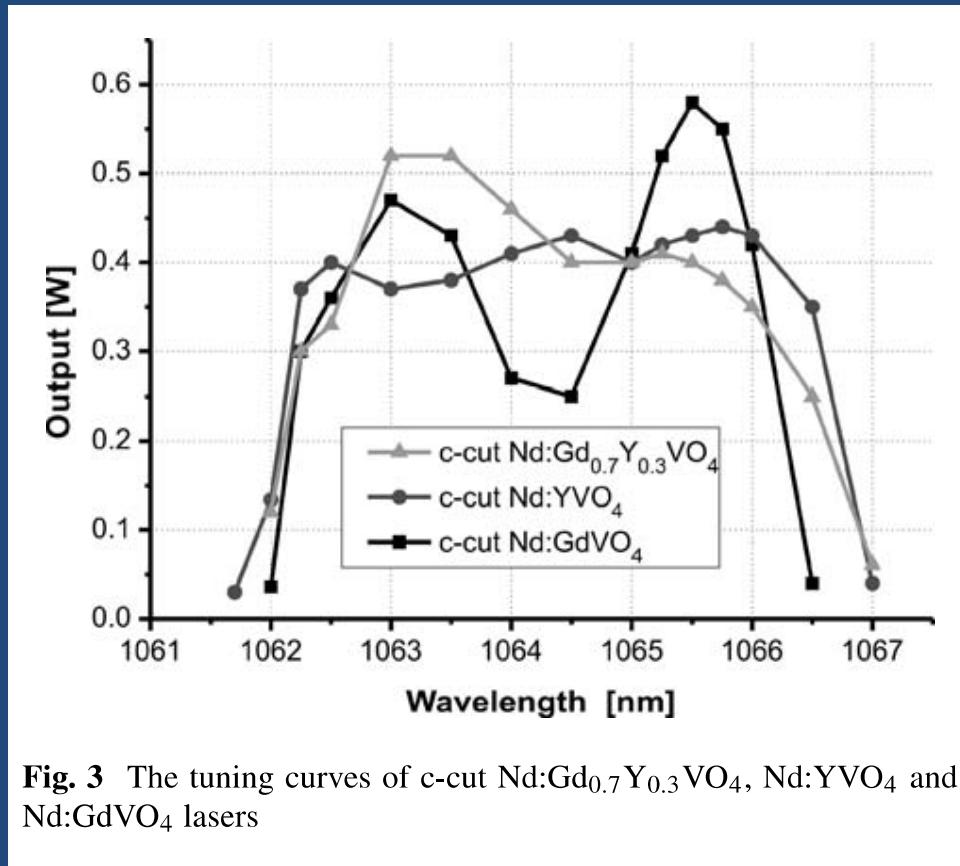


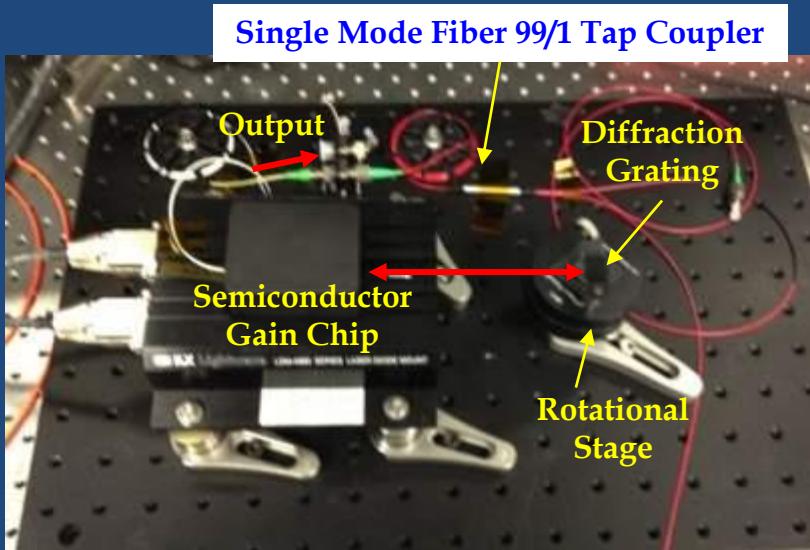
Fig. 3 The tuning curves of c-cut Nd:Gd_{0.7}Y_{0.3}VO₄, Nd:YVO₄ and Nd:GdVO₄ lasers

From: “Mode-locked diode-pumped vanadate lasers operated with PbS quantum dots”

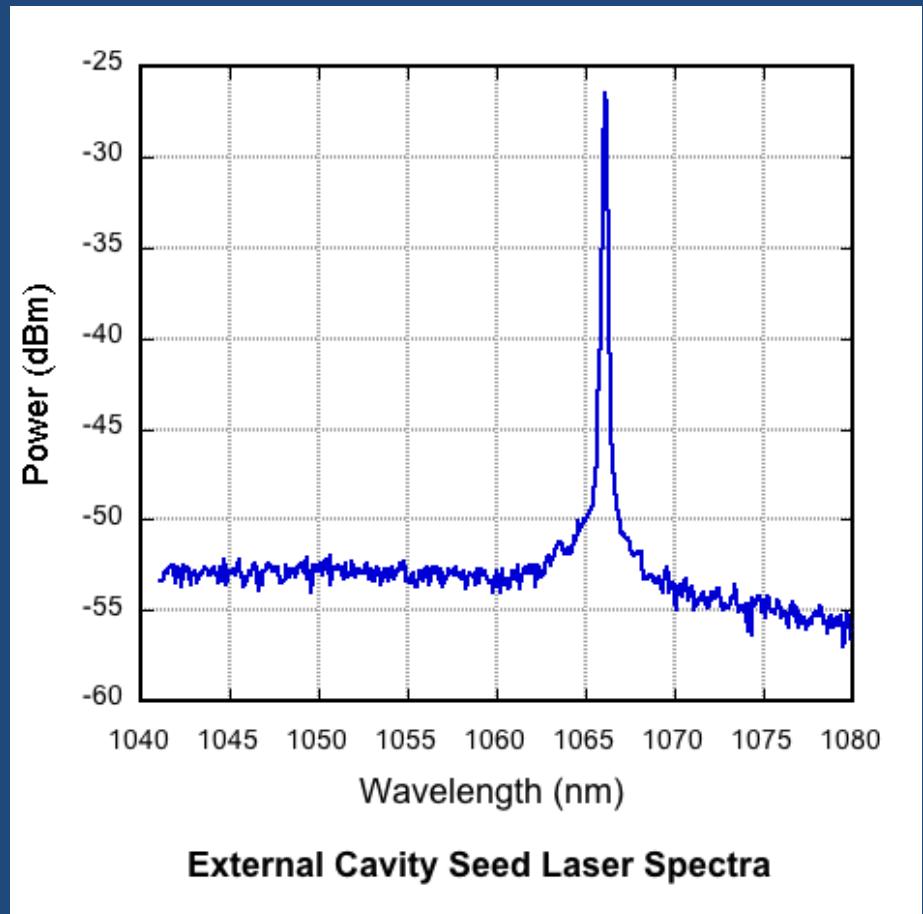
A.A. Sirotkin et al. Appl Phys B (2009) 94: 375–379



1066 nm External cavity laser (ECL) – Tunable injection seeder

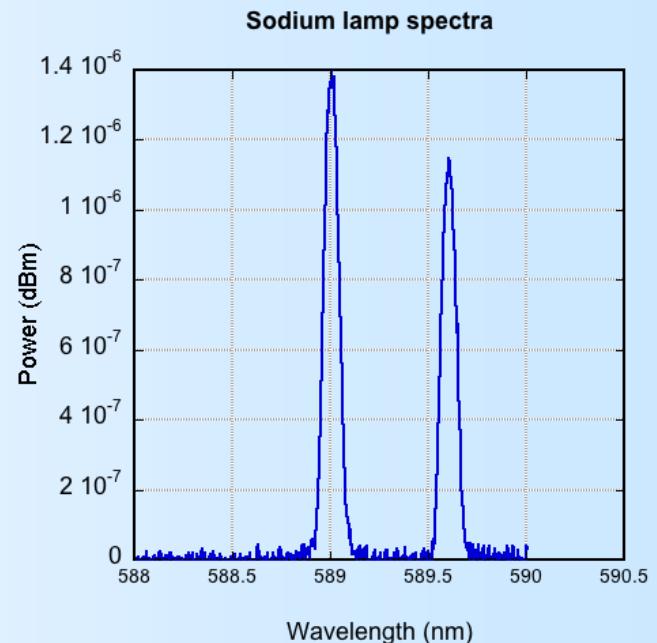
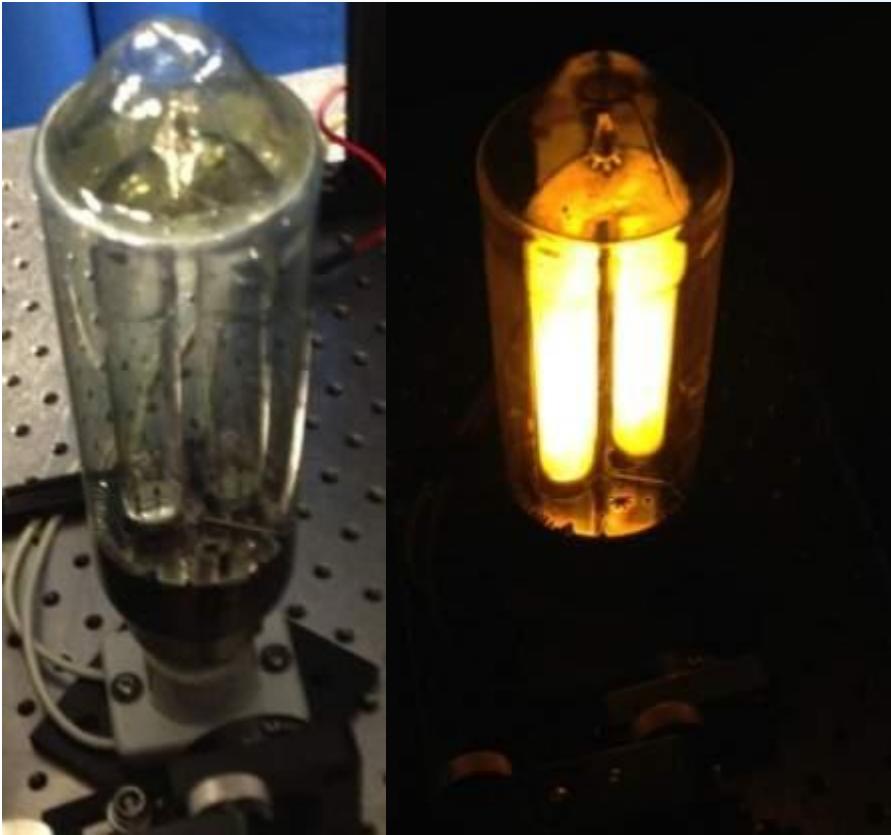


Tunable external cavity seed laser





Sodium line (lamp) calibration source





Sodium lidar instrument

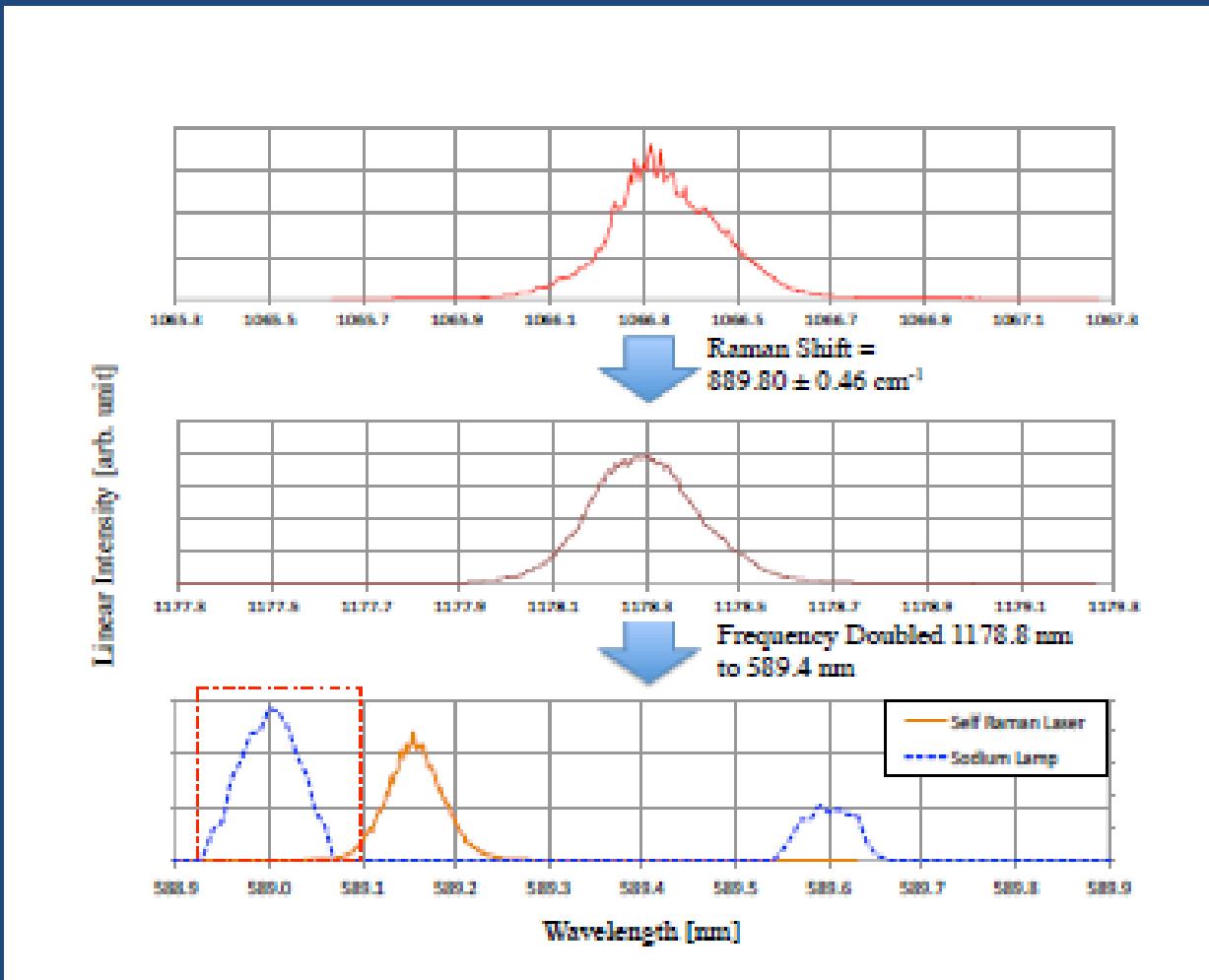
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Self-Raman Nd:YVO₄ laser spectra (unseeded) NASA-GSFC breadboard





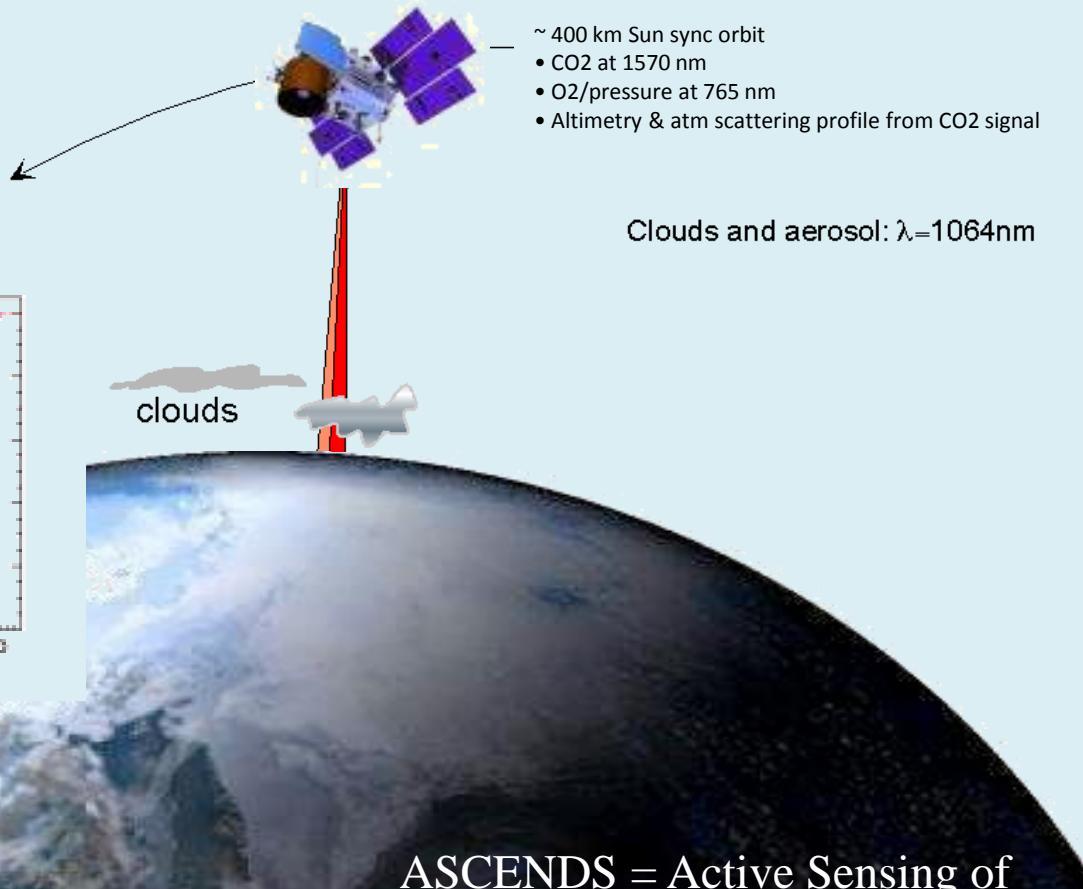
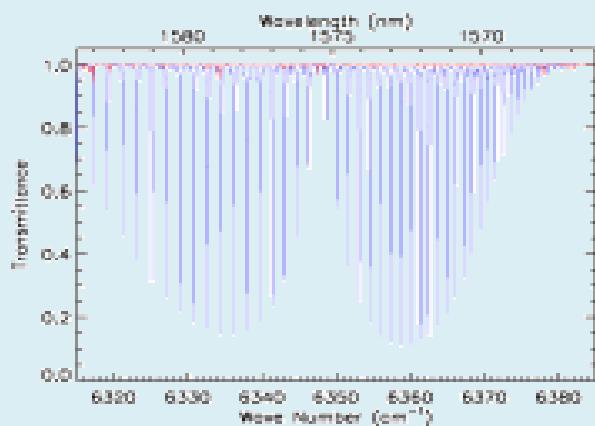
Sodium lidar instrument - leverage

Laser Spectrometer for ASCENDS Mission



Measures:

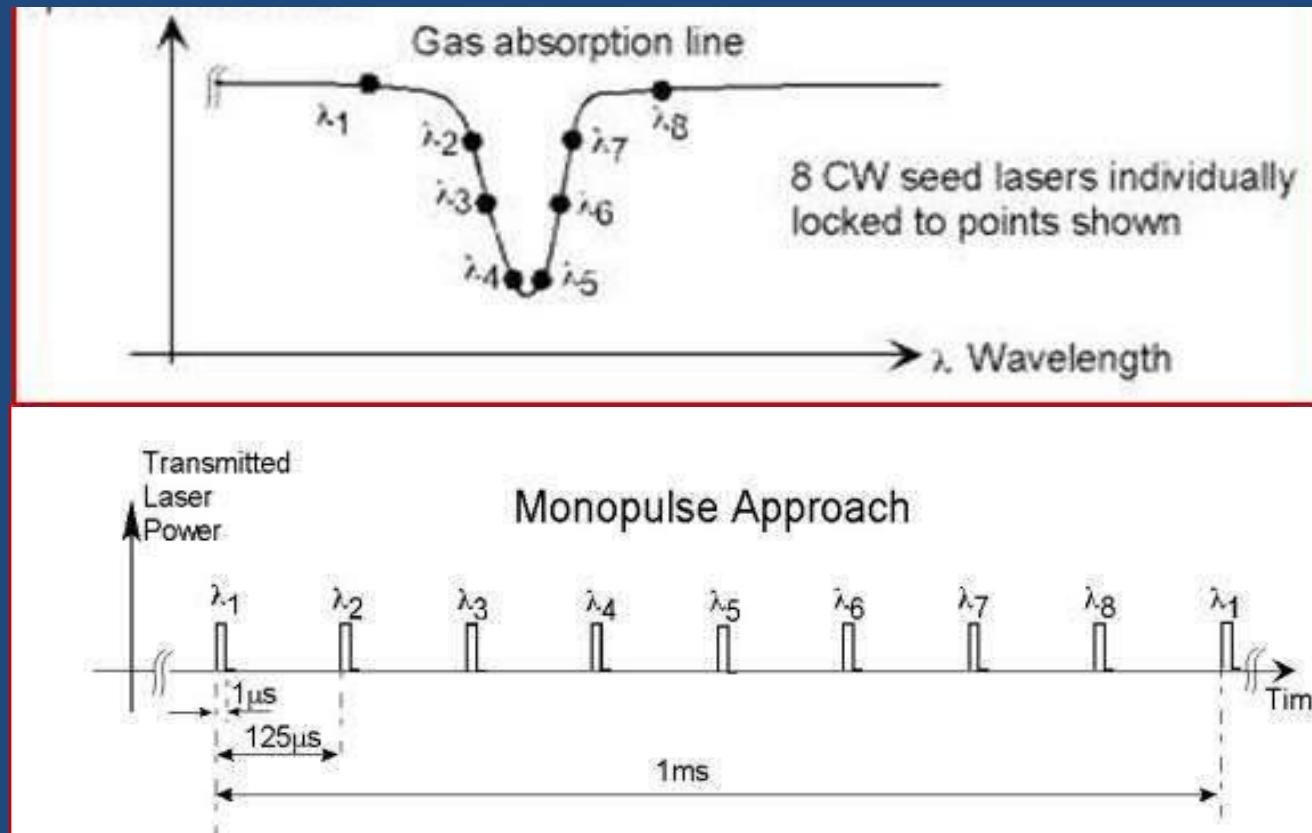
- CO₂ tropospheric column
- O₂ tropospheric column
- Cloud backscattering profile



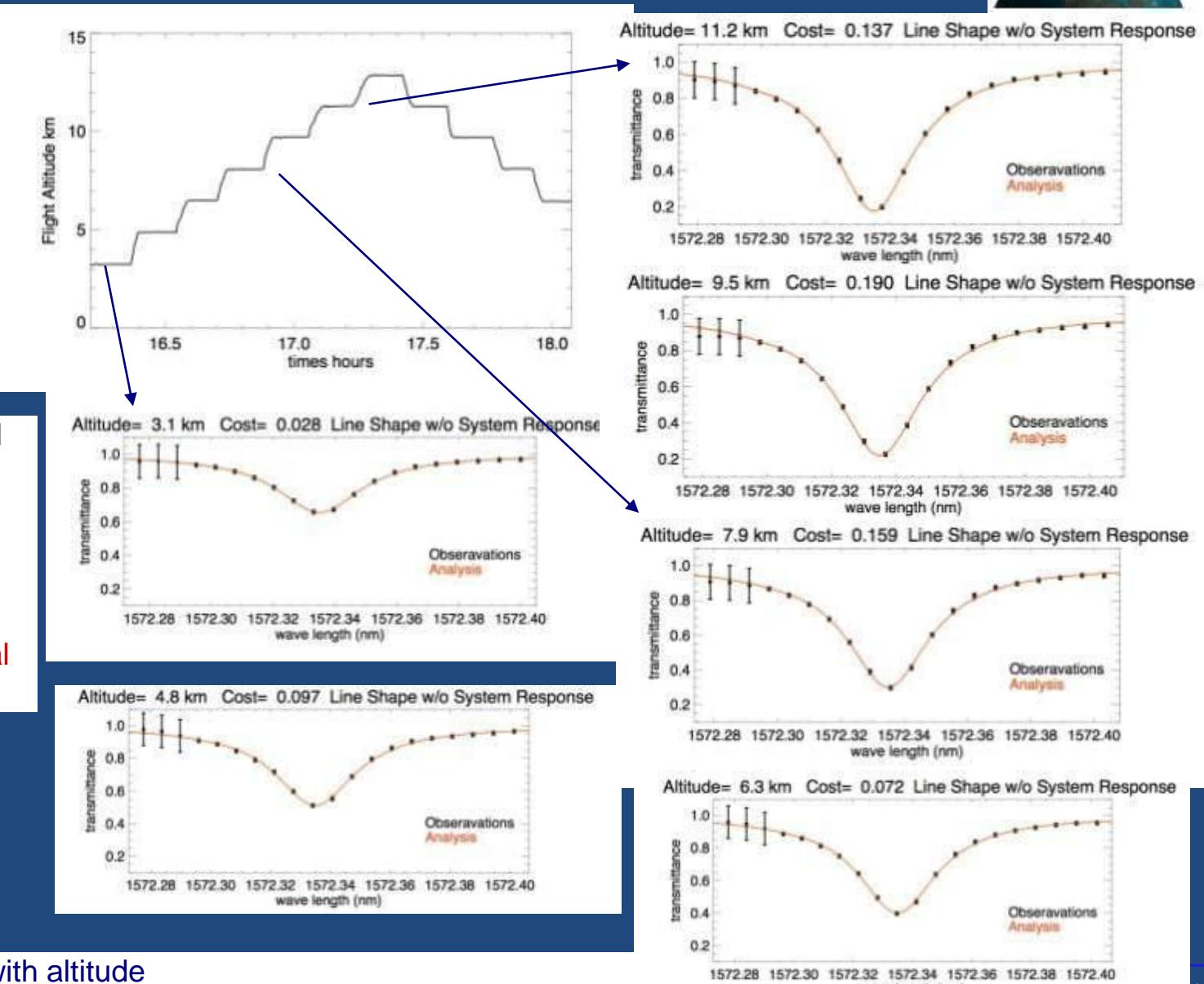
ASCENDS = Active Sensing of
Carbon Emissions over Nights,
Days and Seasons **2022 launch**



Sodium lidar leverage from ASCENDS Mission Time/wavelength multiplexing using electrically tunable DFB laser and modulator



Airborne instrument retrievals of CO₂ absorption line - August 4, 2009



- Black dots - sampled line shape from lidar
• Typ. 60 sec ave time
- Red curves - best fit line shapes (based on HITRAN) from retrieval process
- Absorption increases with altitude
- Smooth line shapes at all altitudes !



Sodium lidar instrument

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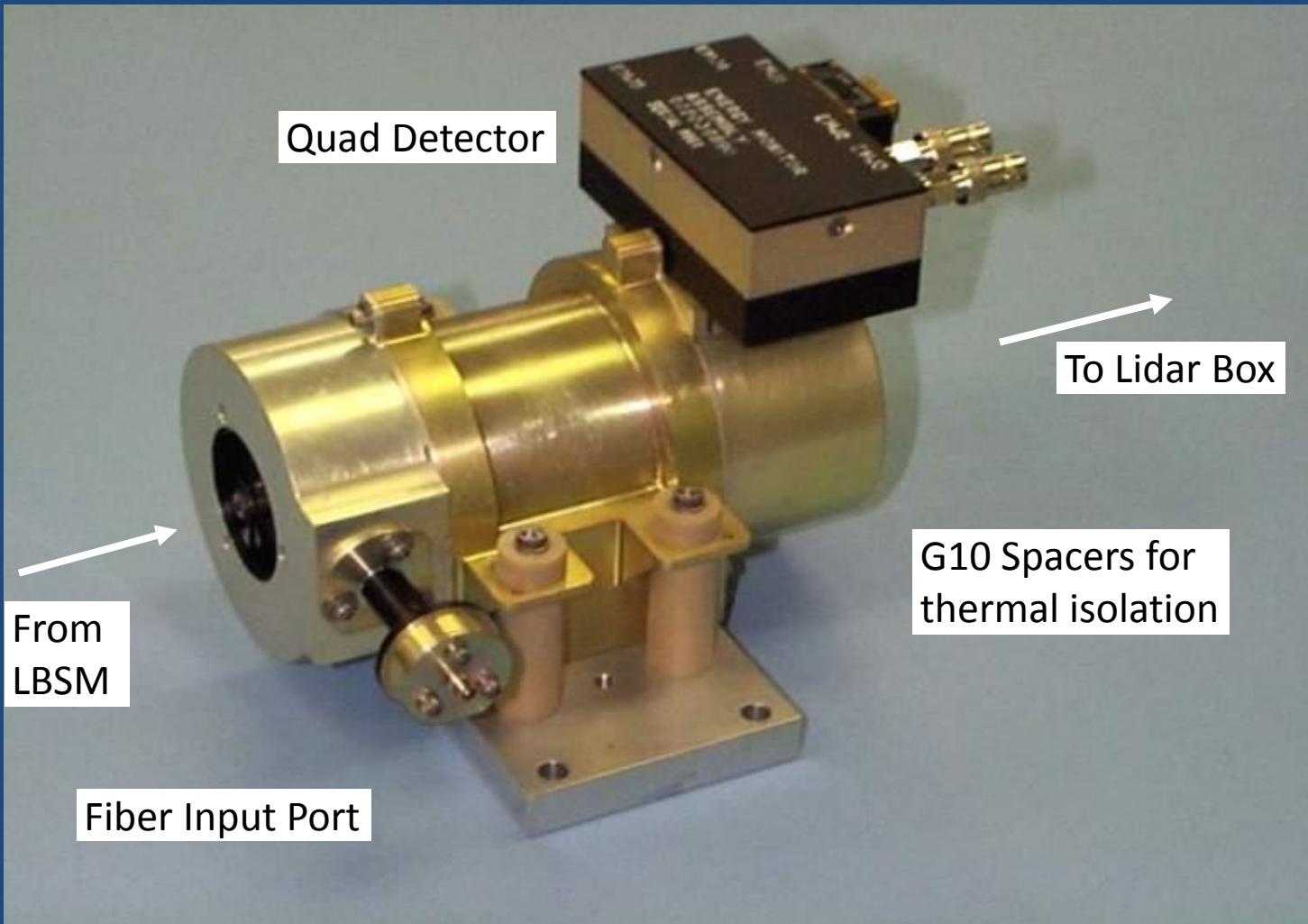
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Sodium lidar leverage from ICESat/GLAS Mission

ICESat/GLAS Etalon Assembly

Also considering sodium vapor Faraday filter





Sodium lidar instrument

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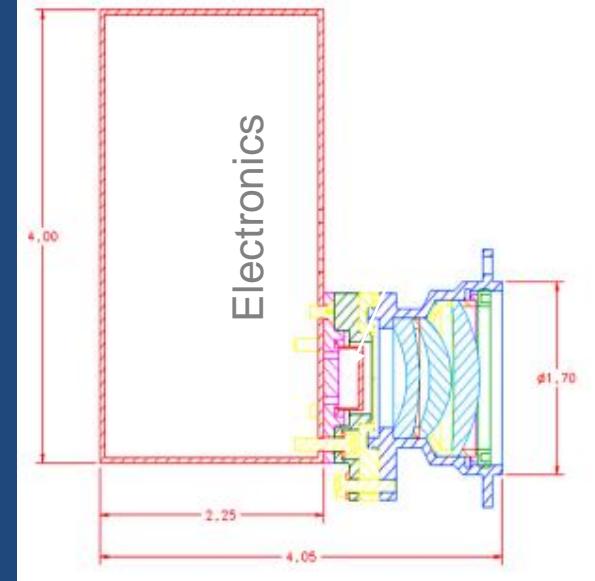
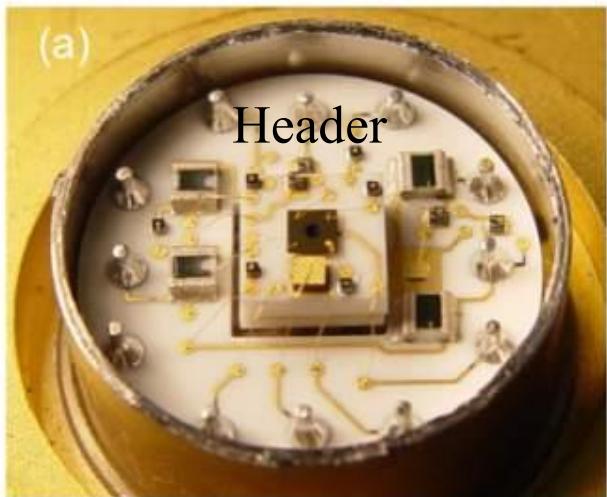


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Sodium lidar leverage from ICESat/GLAS Mission

ICESat/GLAS Single Photon Counting Module (SPCM)



0.17 mm diameter active area
>65% QE at 532 nm
>13e6/s max. count rate
< 1.5% afterpulsing (500ns)
<500/s dark counts
280g (electronics with header)
2.1 W (module only)
4.8 W (with power supply)



Sodium lidar instrument SUMMARY



- NASA-GSFC is exploring concepts for a heliophysics mission using spectroscopy of sodium in the Earth mesosphere
- We have identified key candidate technology for space-based sodium lidar:
 - Laser transmitter: Self-Raman Nd:YVO₄
 - Laser spectroscopic technique: leverage from ASCENDS
 - Laser receiver: filter
 - Laser receiver: single photon detectors
- We have proposed (to NASA Heliophysics) development of a ground-based lidar using space-flight pre-cursor components to evolve to a space-based mission.